



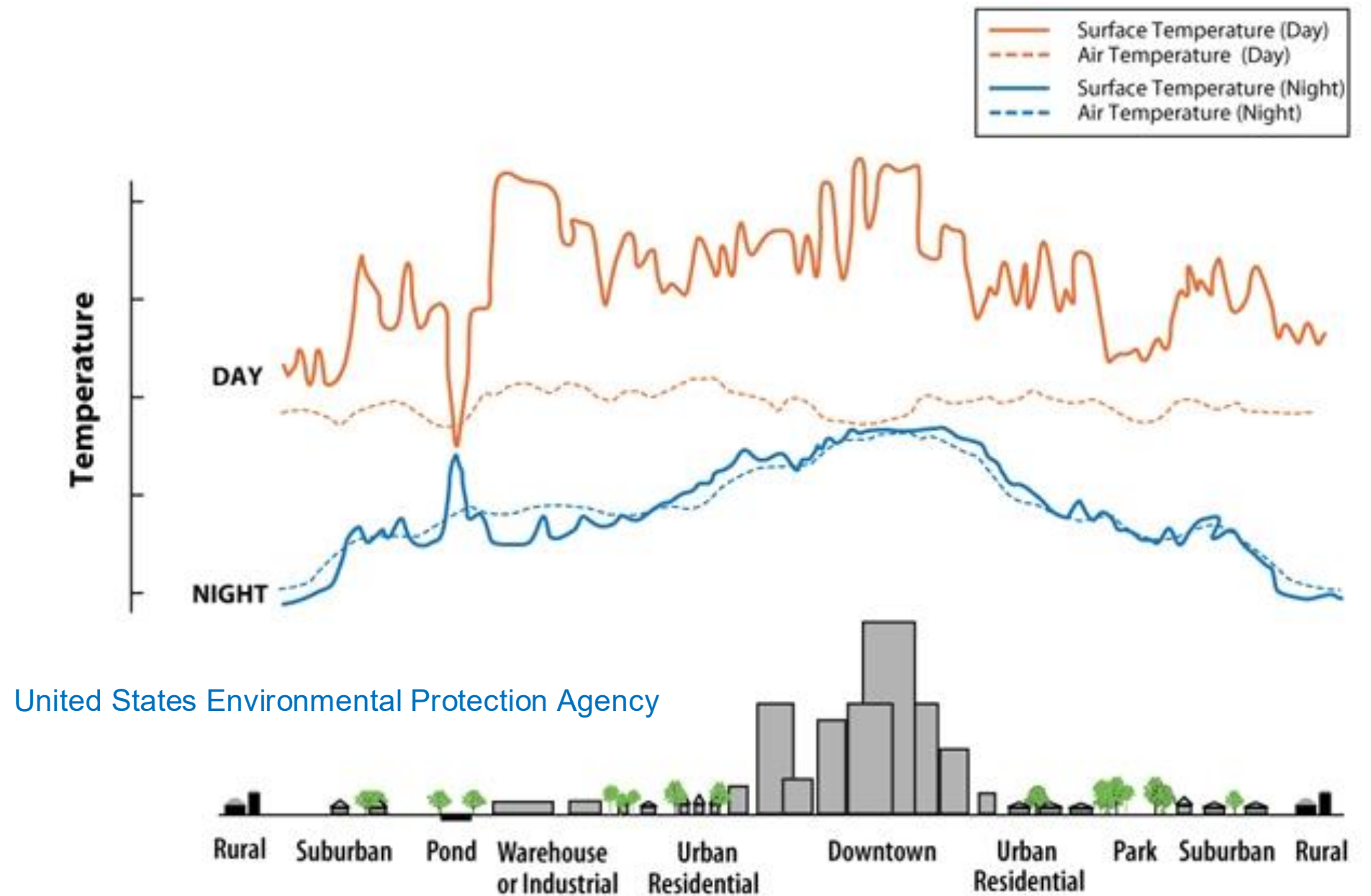
***Rivestimenti organici riflettenti nel NIR:
sinergia tra pigmenti a base perilene e microsfere
cave termoplastiche per superfici fredde***

Andrea Pucci



Urban heat island (UHI) effect

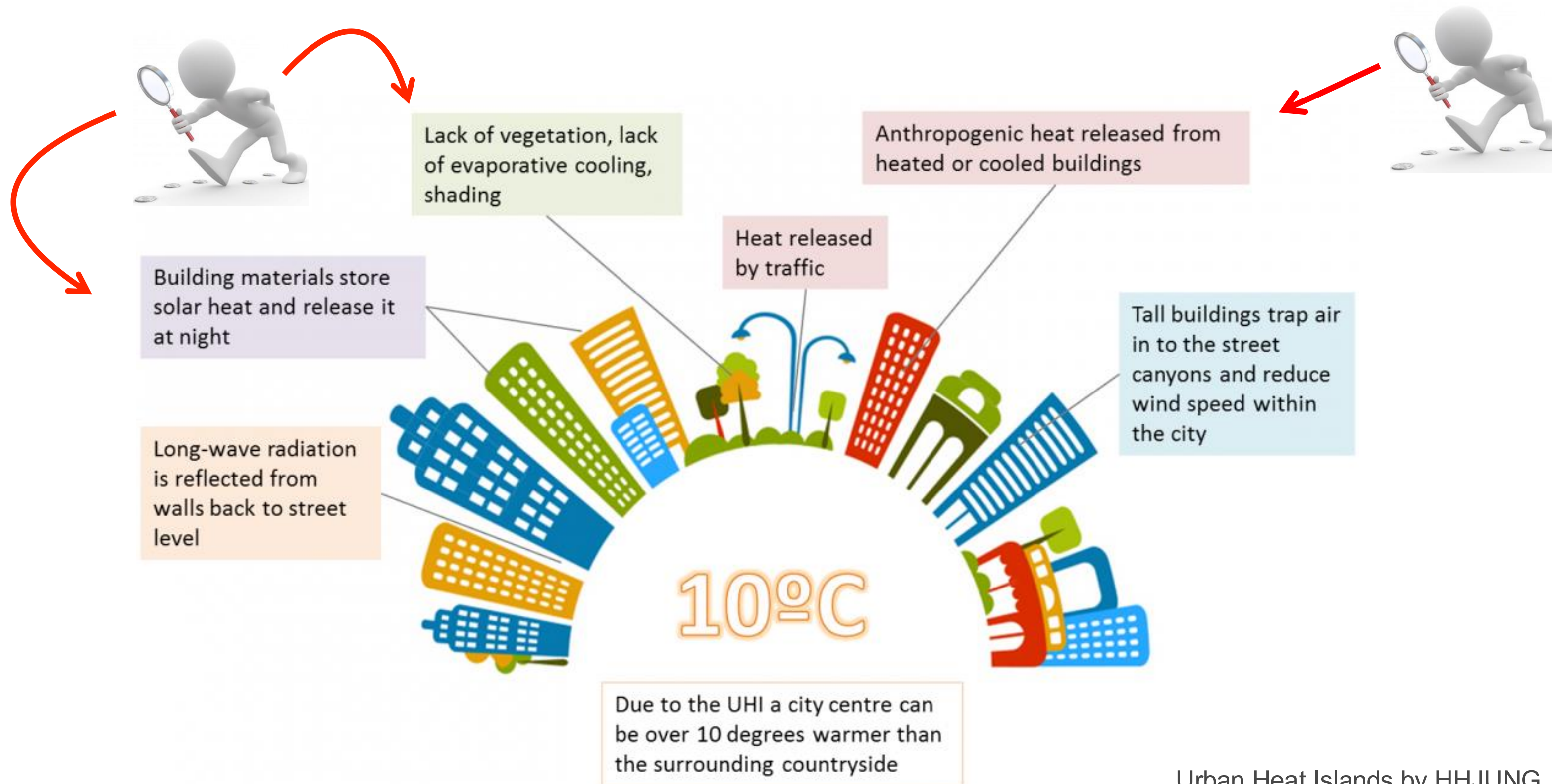
It is widely accepted that human activities contribute to the urban heat island (UHI) effect, making metropolitan areas warmer than surrounding rural regions



Urban Climates and Global Environmental Change. In: Thompson, R.D. and A. Perry (eds.) *Applied Climatology: Principles & Practices*. New York, NY: Routledge. pp. 273-287



Urban heat island (UHI) effect



Urban Heat Islands by HHJUNG

Urban heat island (UHI) effect

Les rues deviennent des jardins



Rue végétalisée Pierre Haret (9e).

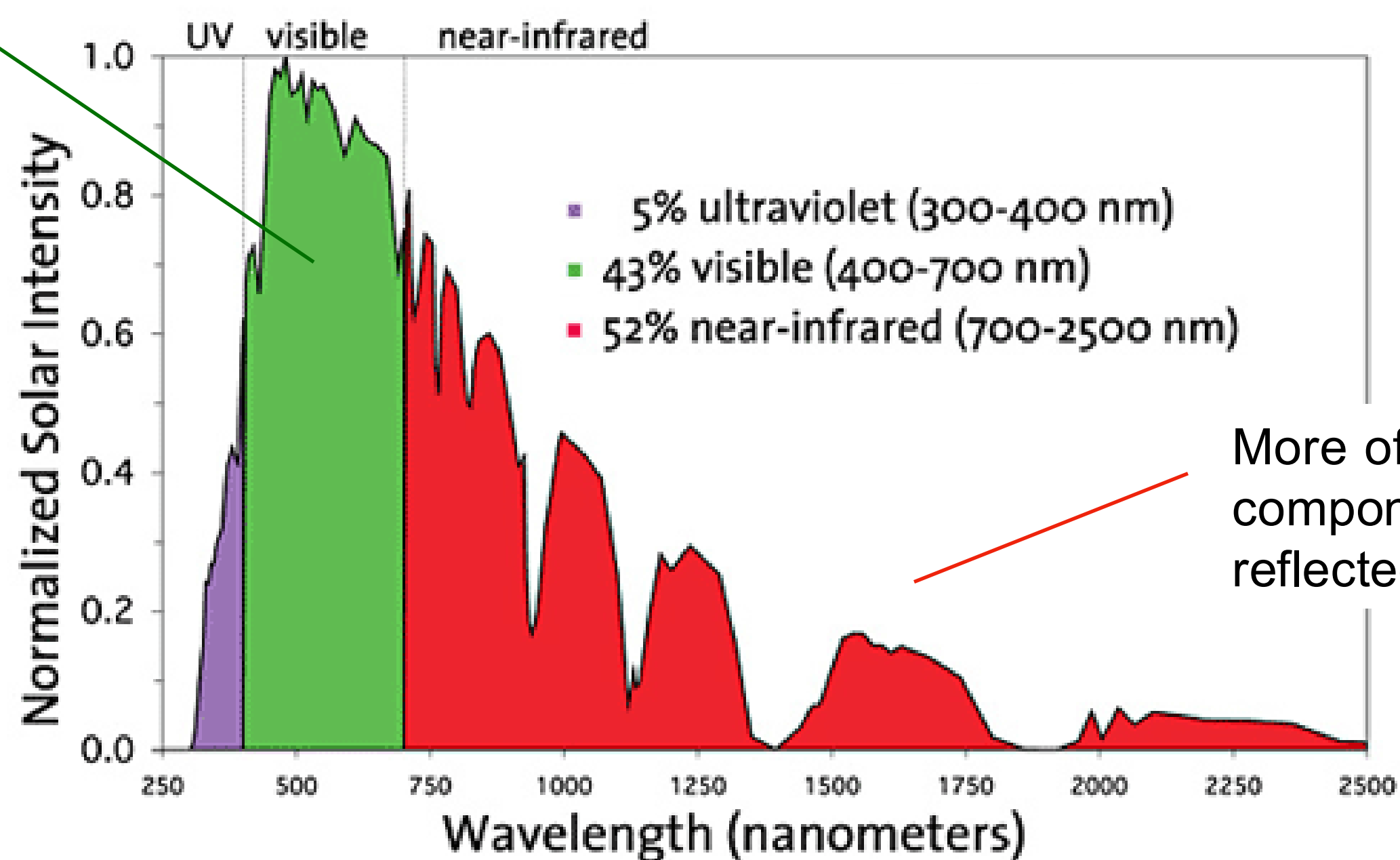
Guillaume Bontemps / Ville de Paris

- 213,000 new trees planted since 2014 (including 15,590 in the 2024–2025 season). The city's original mandate target of 170,000 new trees has already been surpassed.
- Measured/expected local cooling from greening is typically $\sim 2\text{--}4\text{ }^{\circ}\text{C}$ in and around treated spaces (shade + evapotranspiration)

Solar energy distribution

Only 43% of sunlight is responsible of the visible light (color of building walls)

Cool surfaces are characterized by their ability to reflect near-infrared (NIR) solar radiation and to efficiently dissipate heat



More of the 50% of the NIR component should be reflected to avoid heating

Cool NIR reflective pigments

- Cool pigments/coatings can lower surface temperatures by $>10\text{ }^{\circ}\text{C}$, cutting electricity use and mitigating the UHI effect



- White cool pigments (TiO_2) reflect visible light but absorb UV, risking organic coating degradation
- Dark cool pigments, mainly Cr- and rare-earth oxides, offer high refractive index but raise toxicity concerns

Cool Roofs Would Save Los Angeles 83 Million Gallons of Water per day
(*Nature Communications*, 2017, 8, 1072)

Solar reflectance is the most important parameter to determine the cooling effect (*PCI Jan 2017*)



Cool NIR reflective pigments

Heat Reflective Cool Pigments for Paints and Coatings

Paliogen Black, Sicopal Black, Meteor Plus and Xfast Black

BASF's "cool pigment" technologies with optimized spectral behaviors make it possible to formulate dark colors that reduce the heating effect in sunlight by reflecting the near infrared (NIR) portion of the spectrum. Paliogen NIR transparent pigments as well as Sicopal, Meteor Plus and Xfast NIR reflective pigments offer increased surface reflectivity and reduced surface heat build-up in coatings.

All dark surfaces that are exposed to sunlight heat up strongly, while light surfaces remain distinctly cooler. This is because dark surfaces absorb incident sunlight and convert it into heat, while light surfaces reflect more of the incoming energy.



Features

- Increased surface reflectance
- Reduced surface heat build-up
- Lower energy usage through lower cooling requirements
- Longer lifetimes for coatings through reduced temperature strain

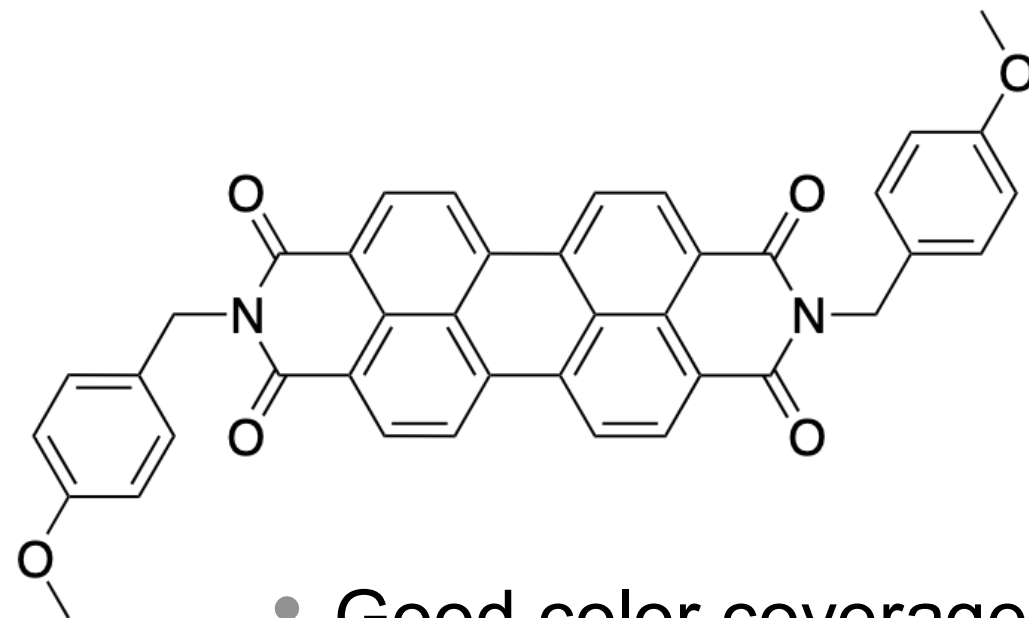
<https://aerospace.basf.com/heat-reflective-cool-pigments.html>

Cool NIR reflective pigments

B. Kaur, et al., Dyes and Pigments, 99 (2013) 502

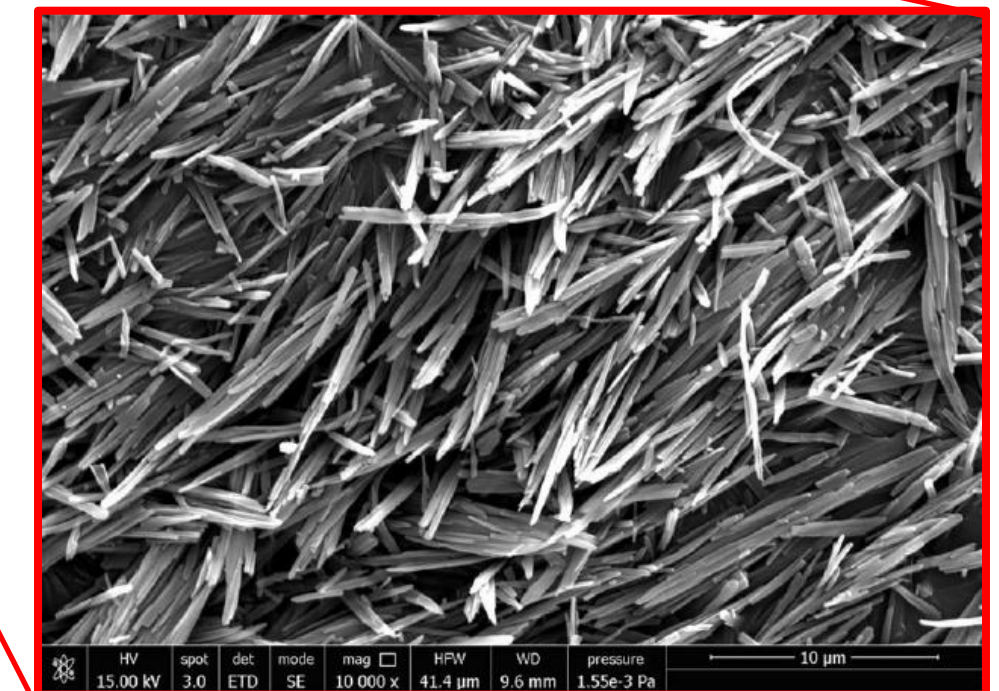
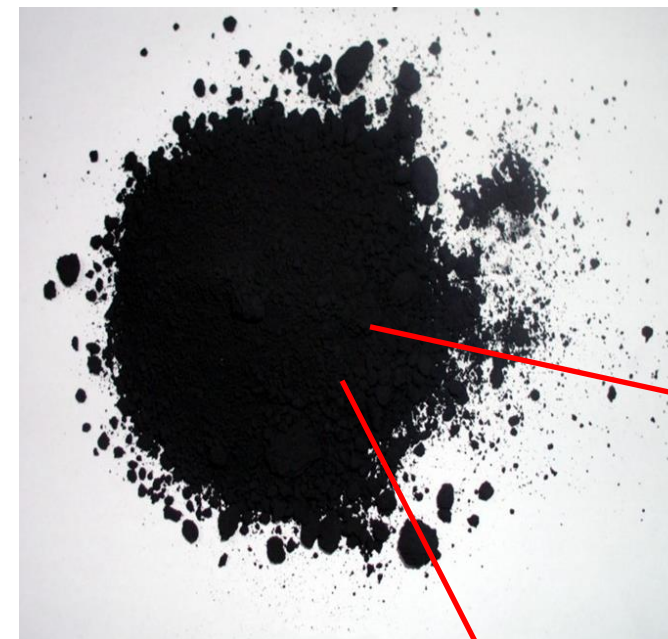
O. Sandin, et al., Journal of Coatings Technology and Research, 14 (2017) 817

Pigment black



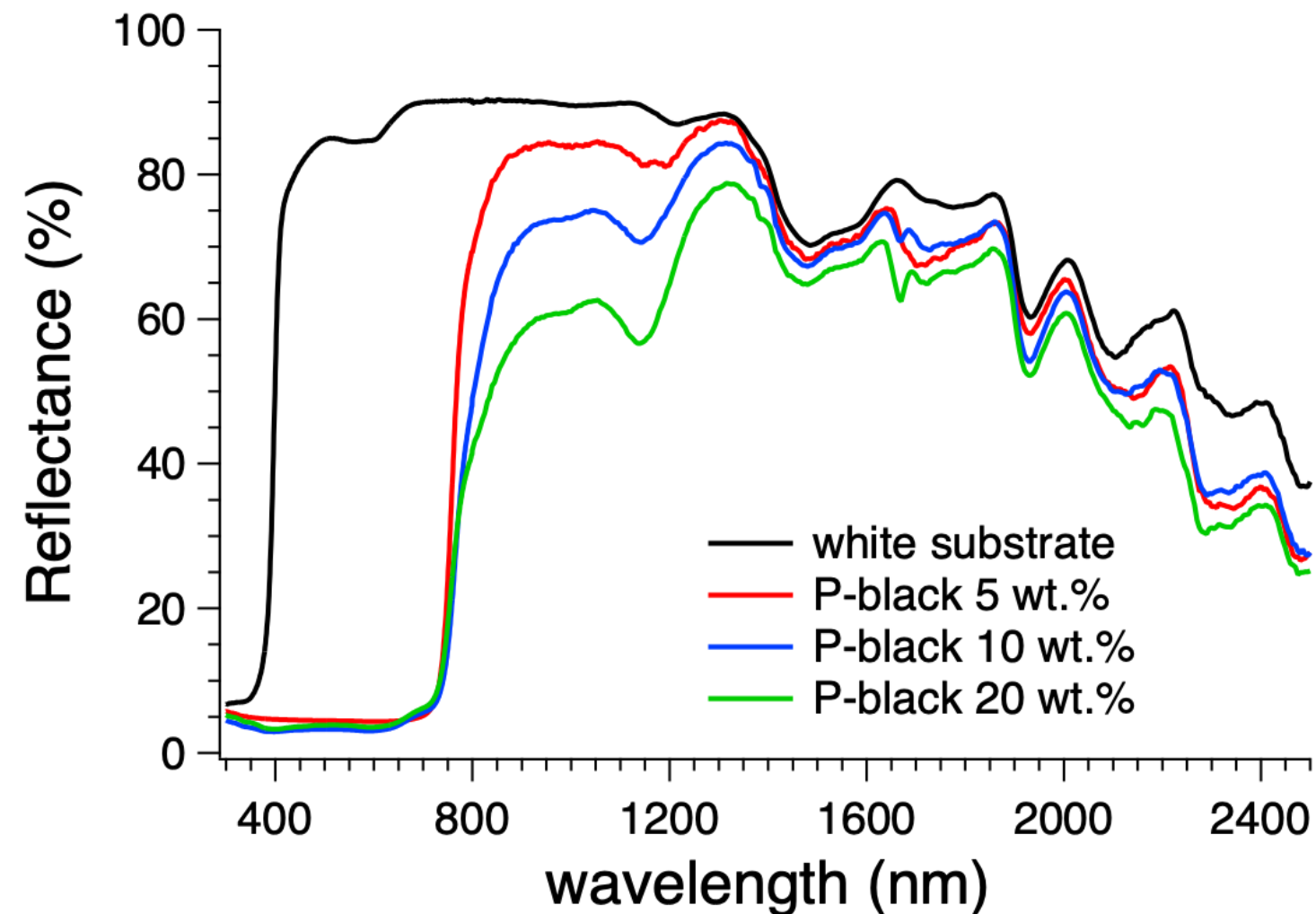
- Good color coverage
- NIR transparent
- NIR reflectivity

NIR reflectivity due to pigment particle size, crystallinity and dipole moment

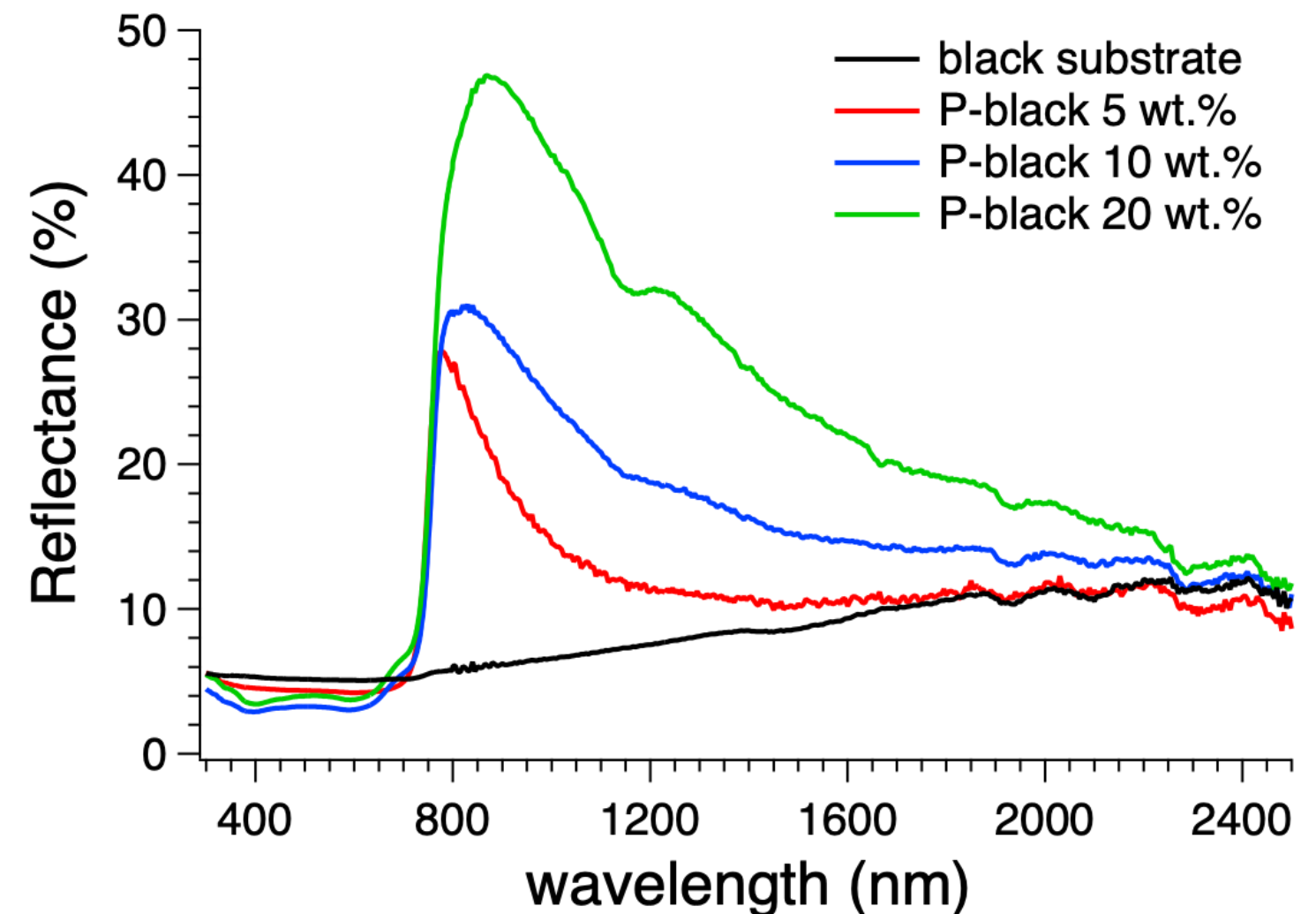


Cool NIR reflective pigments

White Leneta



Black Leneta

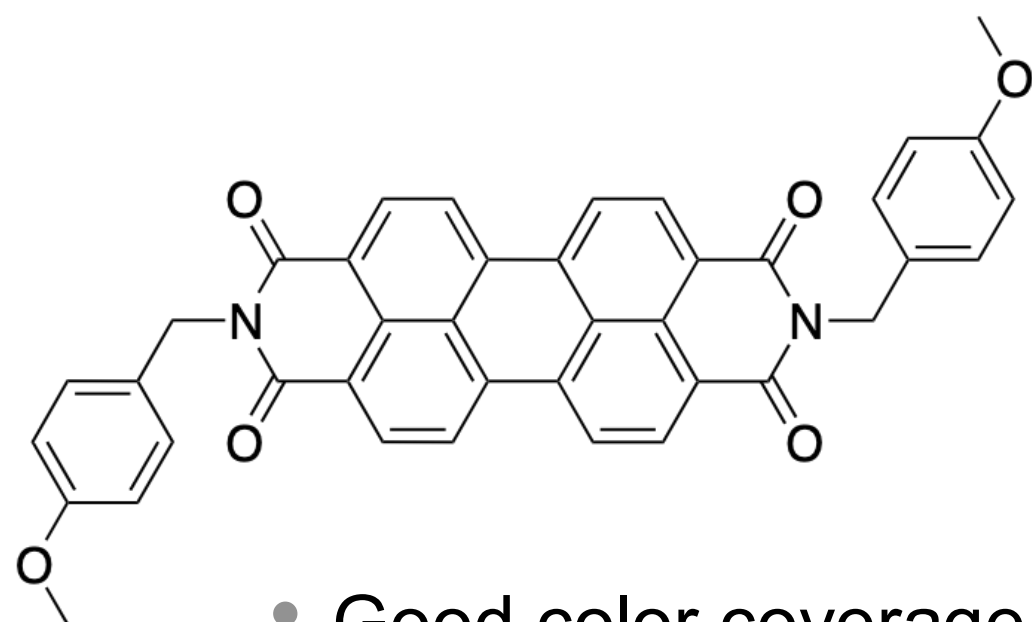


- R% increased in the 800-1200 nm interval up to 48% but at contents of about 20 wt.%!
- NIR reflectivity -> crystalline nature of symmetric perylene bisimides (65% by XRD)

Aim of the work

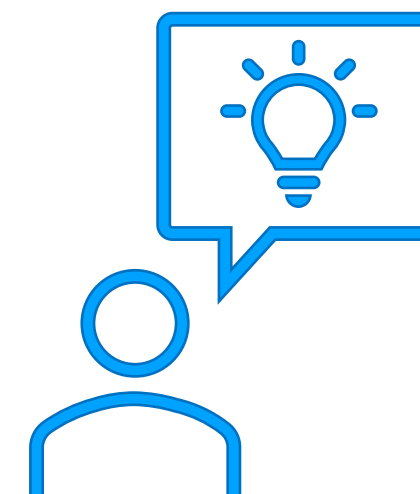
Organic cool pigments such as perylenes exhibit NIR transparency and reflectivity, but their reflectance on black substrates still requires improvement

Pigment black



- Good color coverage
- NIR transparent
- NIR reflectivity

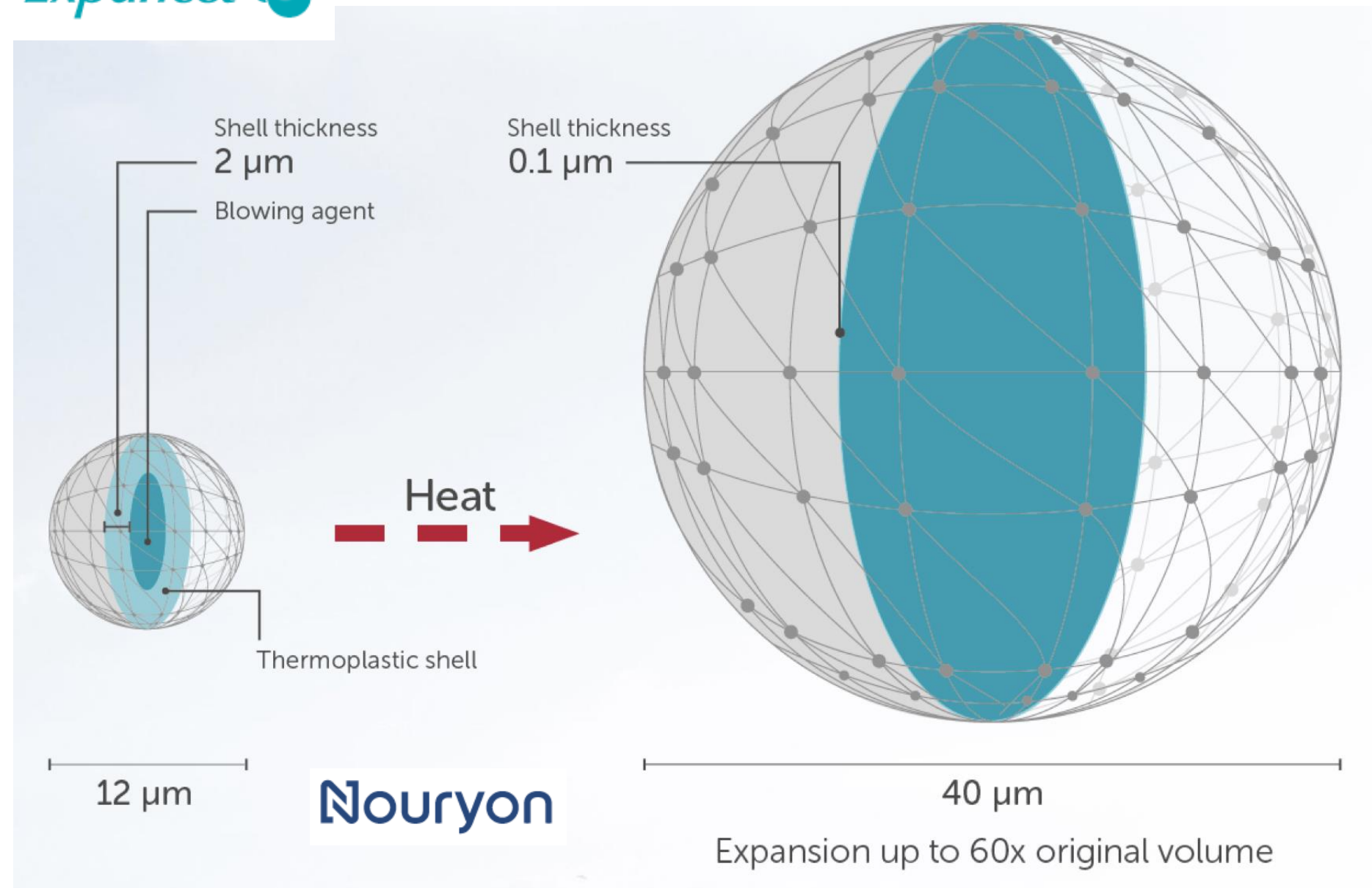
+



Thermoplastic hollow microspheres

Thermally expandable core/shell acrylonitrile-vinylidene chloride methyl-methacrylate copolymer particles encapsulating isobutane

Expancel®



Food Packaging

High compressibility, no shrinkage, no moisture absorption

Genuine leather

Outstanding filling capacity, low shrinkage and good buffing properties.

Shoe soles

Low weight, durability, shock absorption.

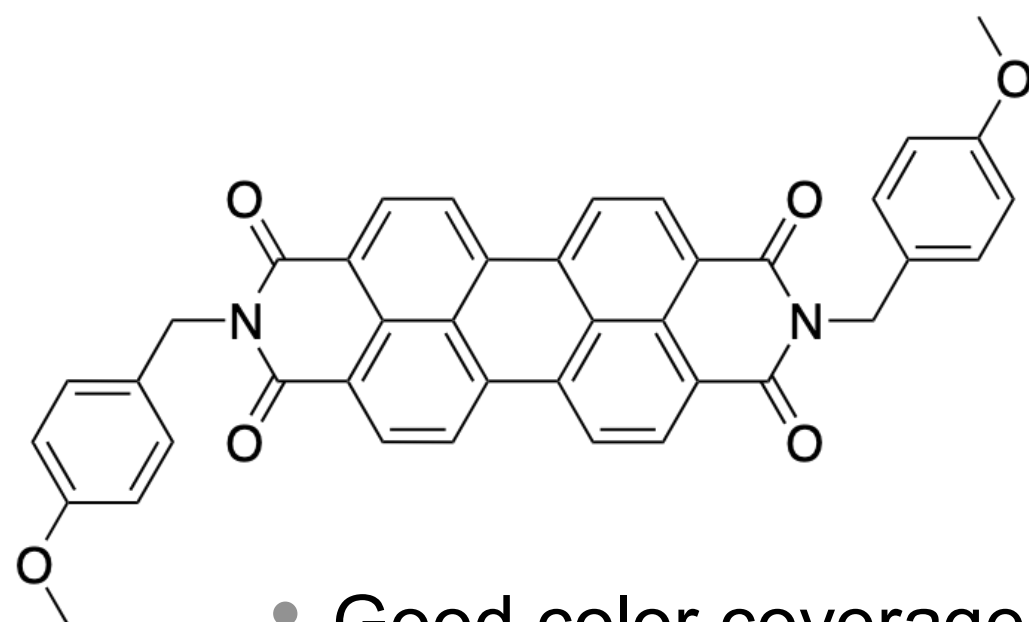
Automotive

Reduce weight, dampen sound, improve sealing.

Aim of the work

Organic cool pigments such as perylenes exhibit NIR transparency and reflectivity, but their reflectance on black substrates still requires improvement

Pigment black



- Good color coverage
- NIR transparent
- NIR reflectivity

+

Elastomeric cool-roof coatings

Superior reflectance and elasticity. Reduces cost and weight.



The refractive index contrast makes them strong NIR scatterers, and multiple scattering boosts overall diffuse reflectance

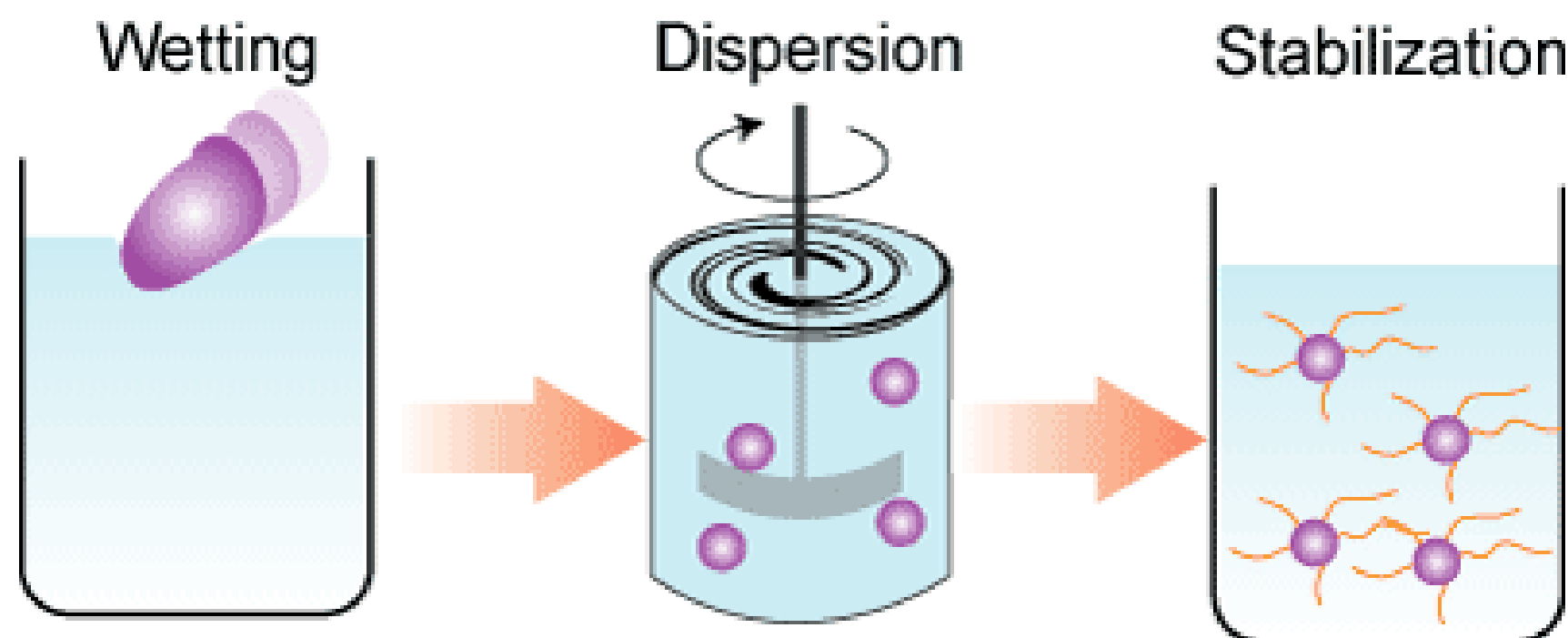
P. Minei, et al., *Solar Energy*, 2020, 198, 689

F. Martini, et al, *Dyes and Pigments*, 2020, 179, 108401

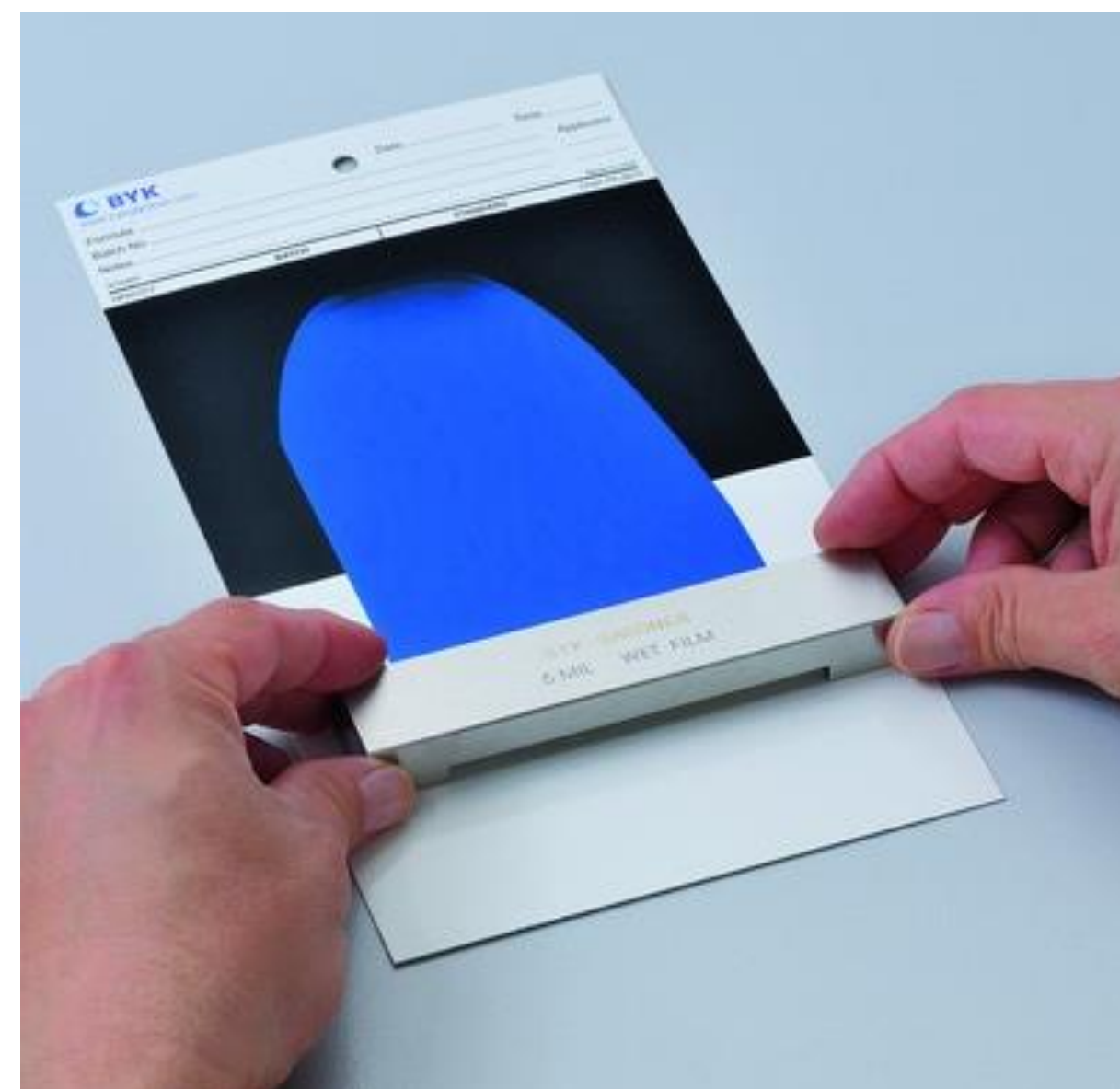


Cool NIR reflective organic pigments with THM

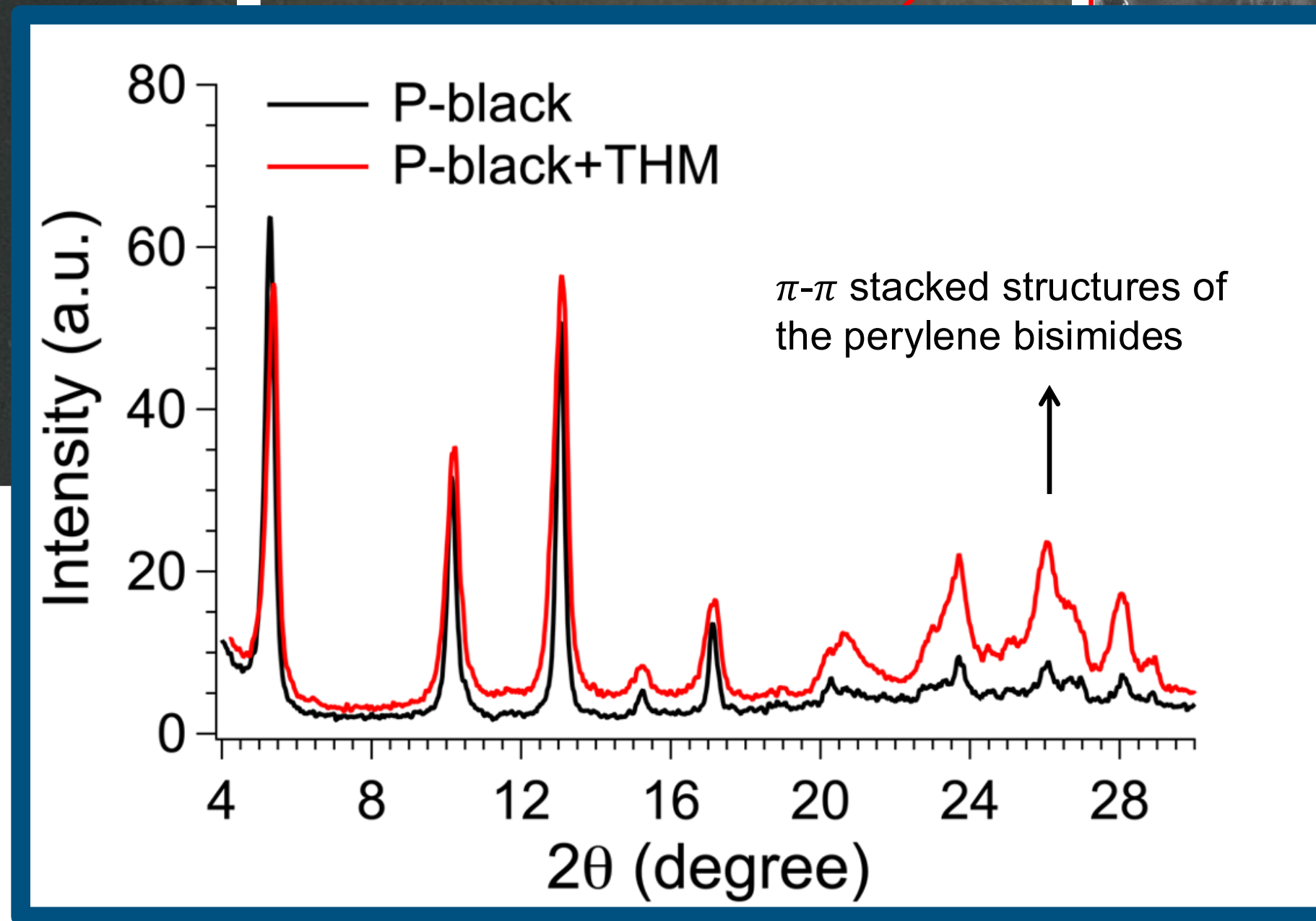
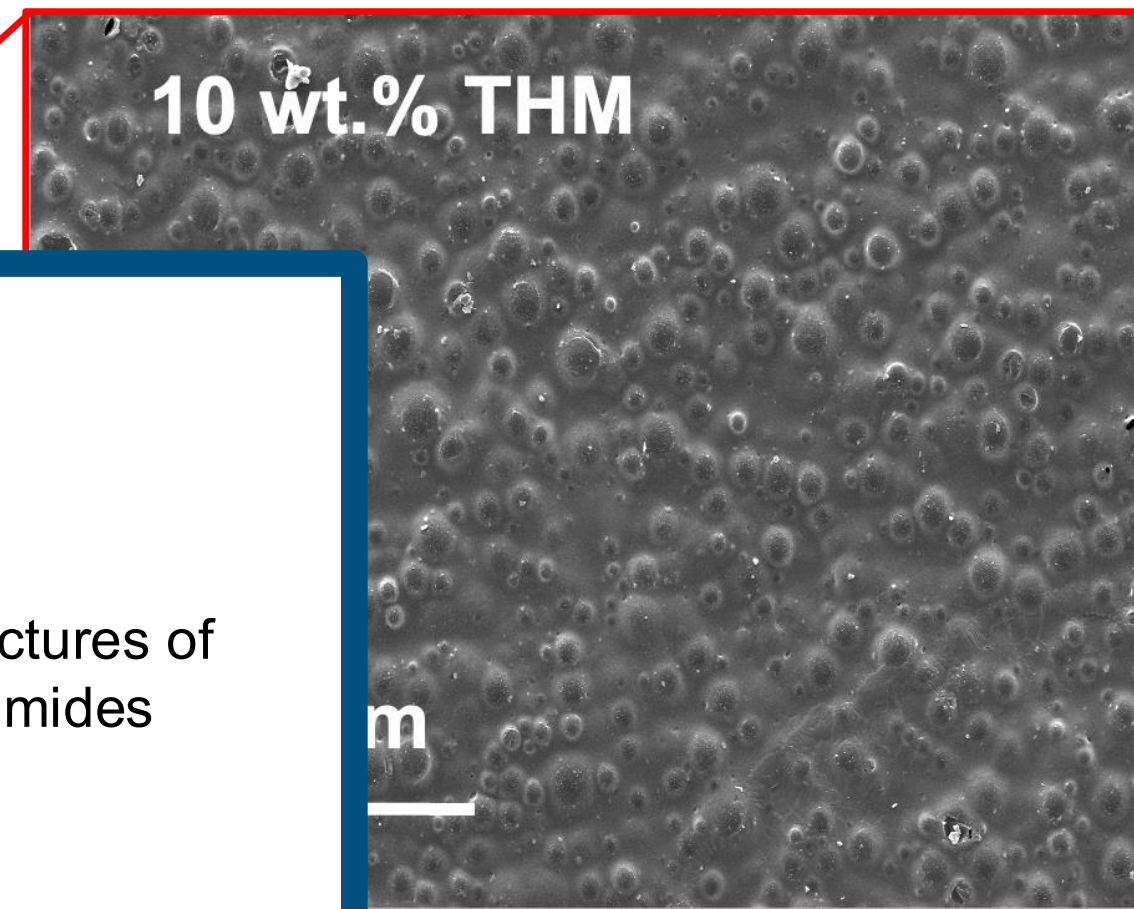
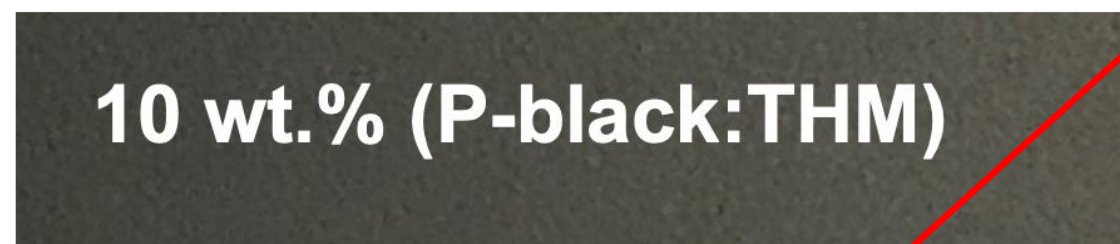
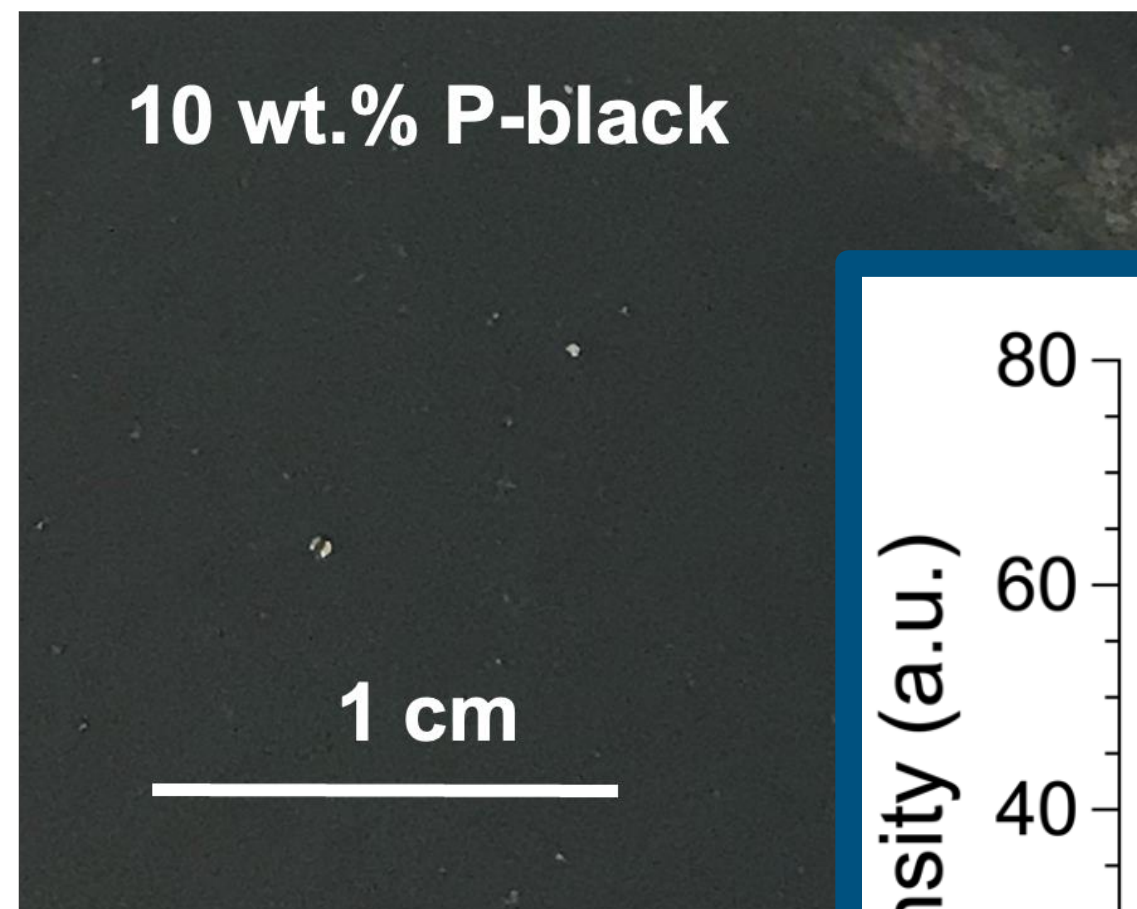
Pigment water acrylic dispersions with or without the thermoplastic hollow microspheres (THM) were coated at different thickness (from 75 to 255 μm) onto the white and black substrates of Leneta[®] checkboards.



5-10 wt.% P-black (+THM)
Wetting agent (1:1 by weight)
2 g of acrylic resin dispersed in water

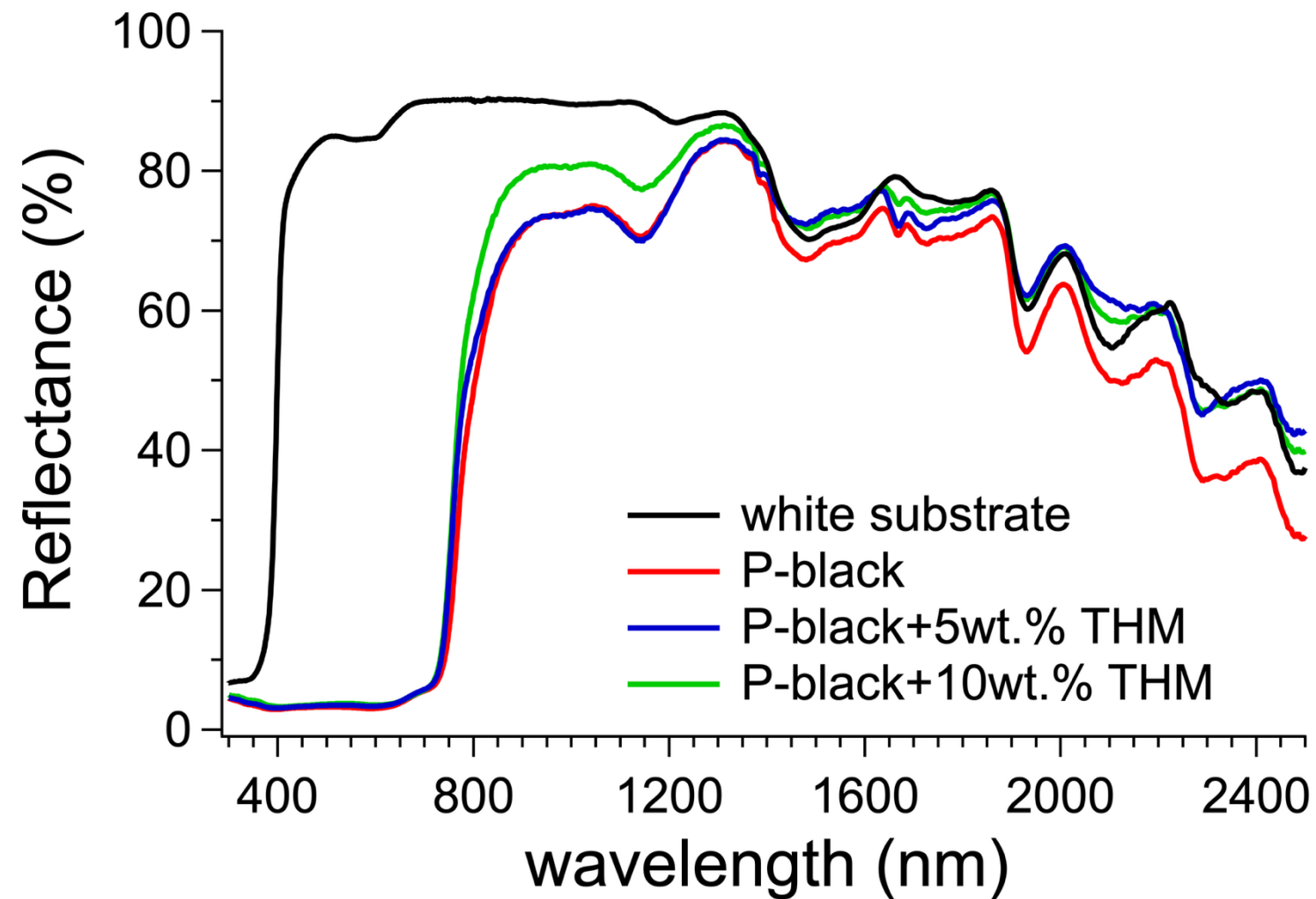


Cool NIR reflective organic pigments: WITH THM

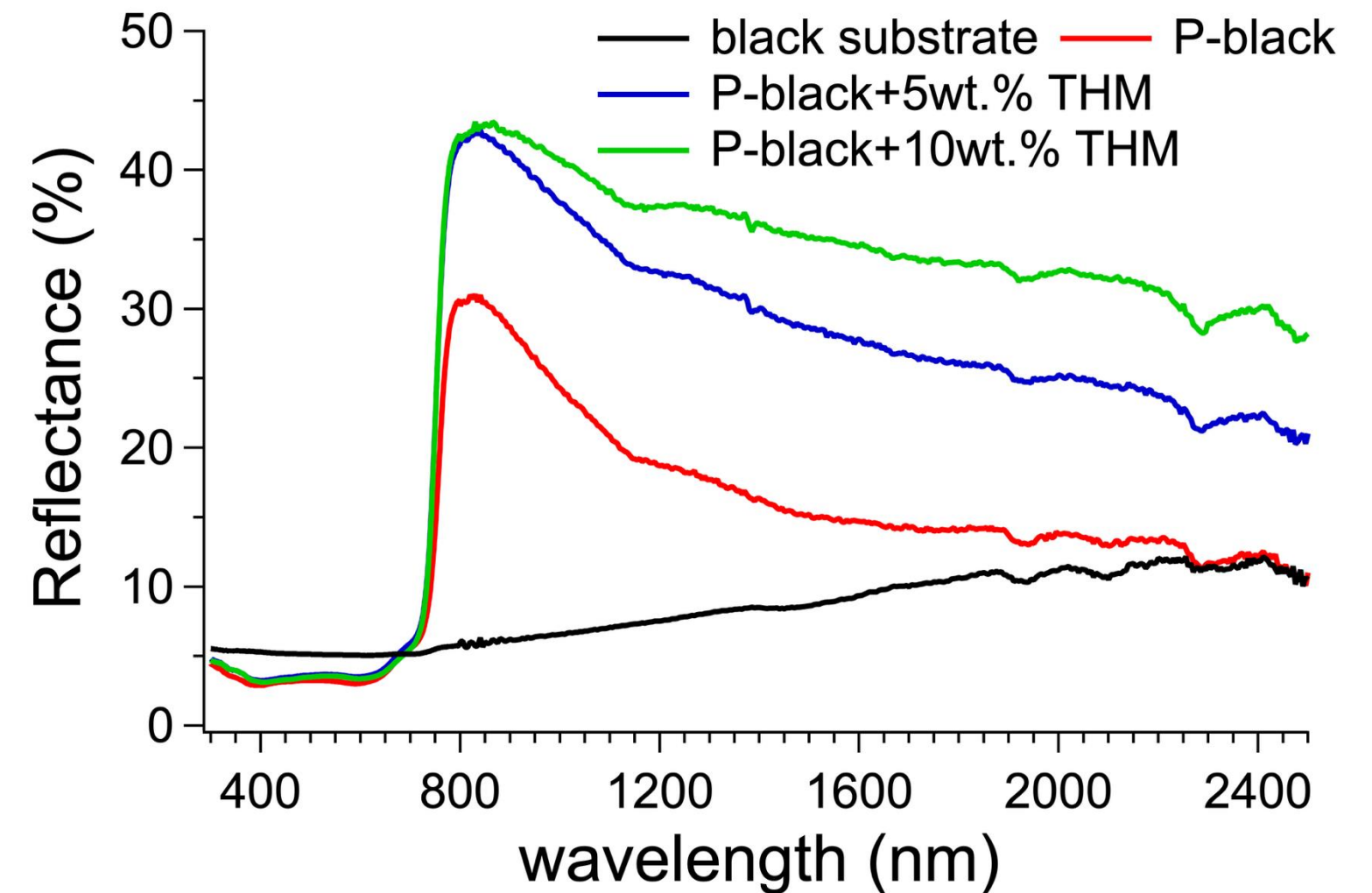


Cool NIR reflective organic pigments: WITH THM

White Leneta



Black Leneta

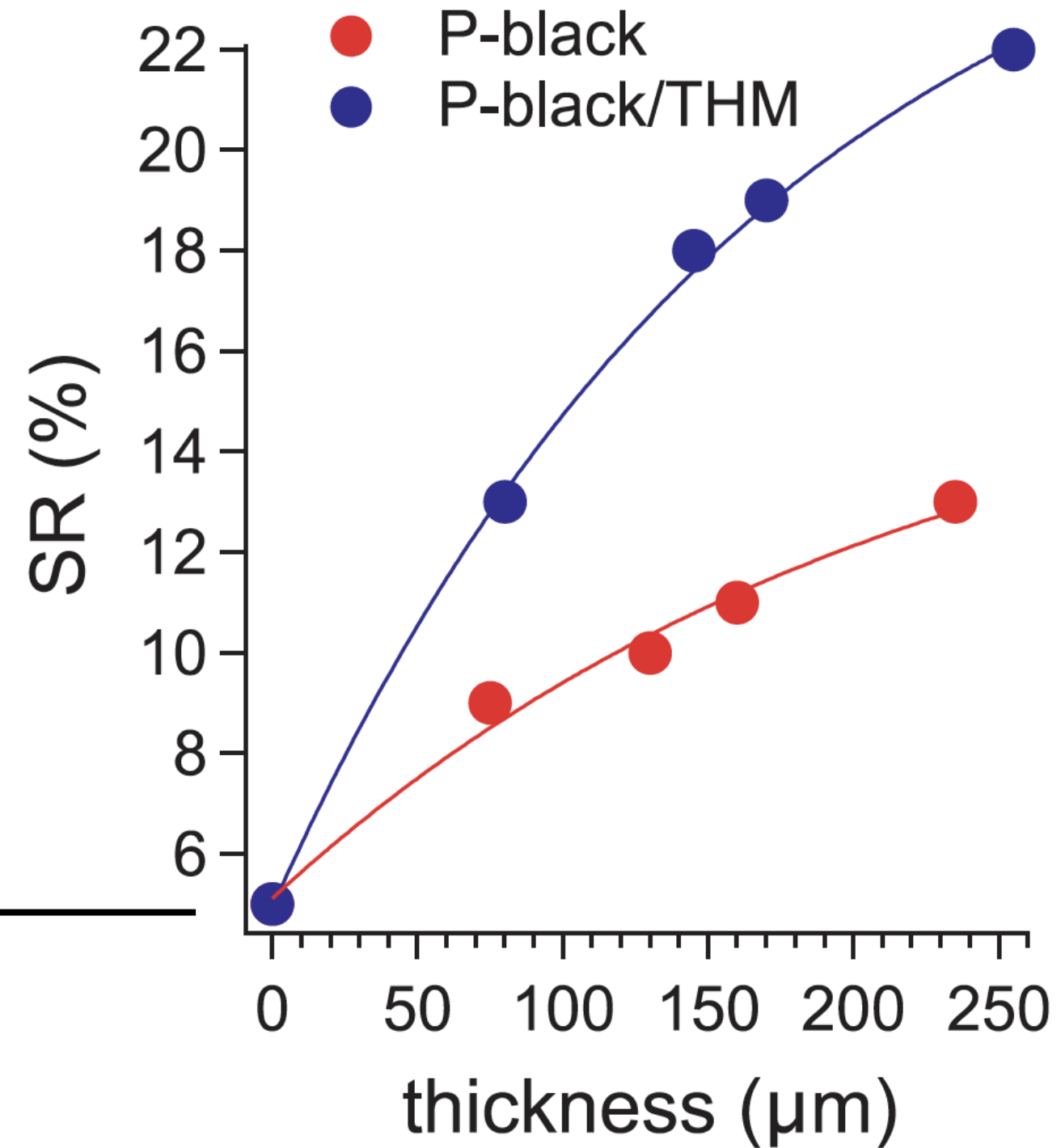


The addition of 5-10 wt.% of THM to the 10 wt.% of P-black coatings boosted the reflectance of more than 40%. Possible synergic effect between P-black and THM

Cool NIR reflective organic pigments: WITH THM

Total solar reflectances (SR, i.e. amount of reflected light weighted with the air mass 1.5 beam-hemispherical solar spectral irradiance for 37° sun-facing tilted surface, ASTM G173-03).

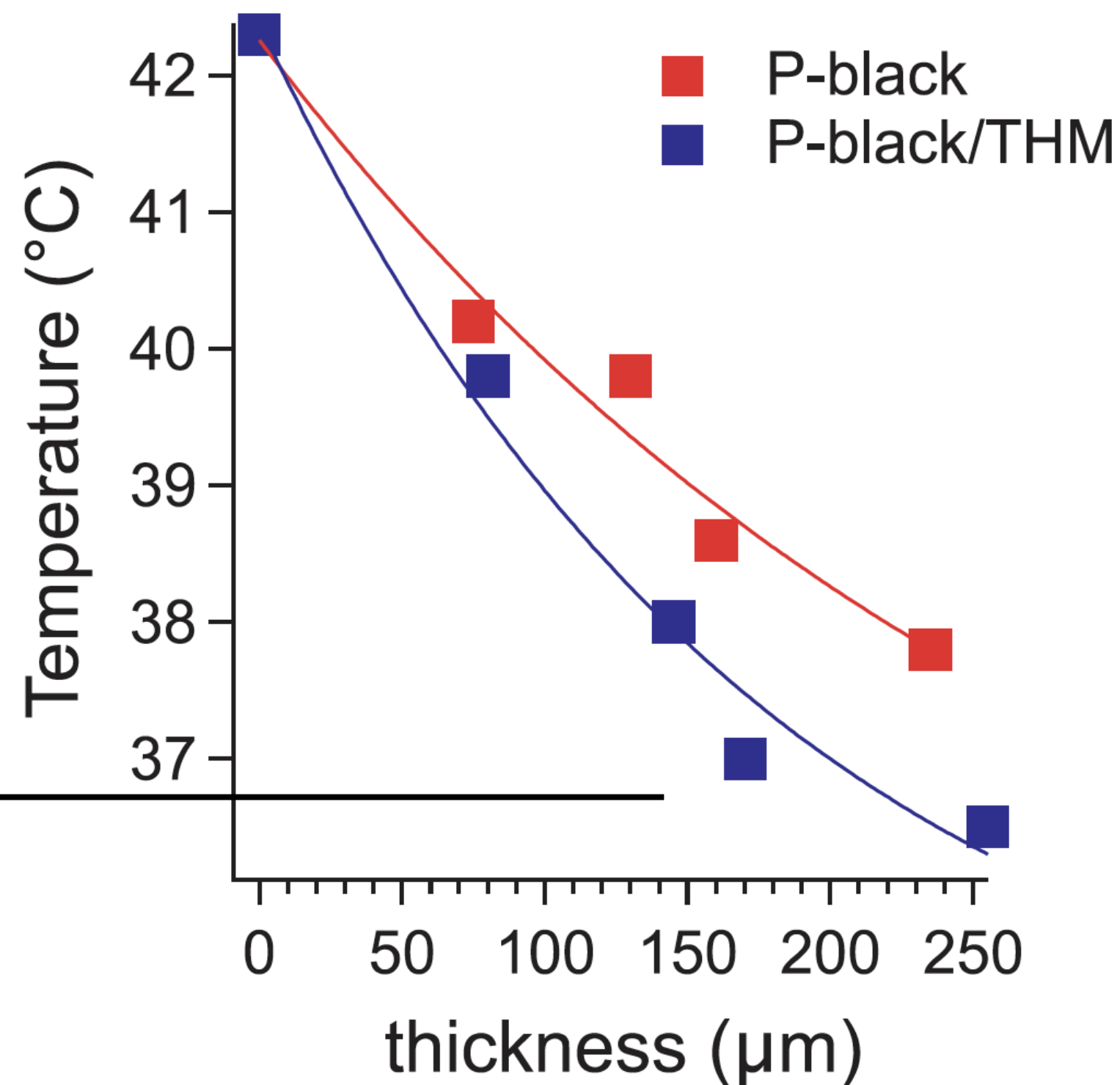
Normally, SR of about 5-7 % are characteristics of black or dark pigmented surfaces.



Cool NIR reflective organic pigments: WITH THM

Backside temperature was recorded after 15 min solar-simulator irradiation

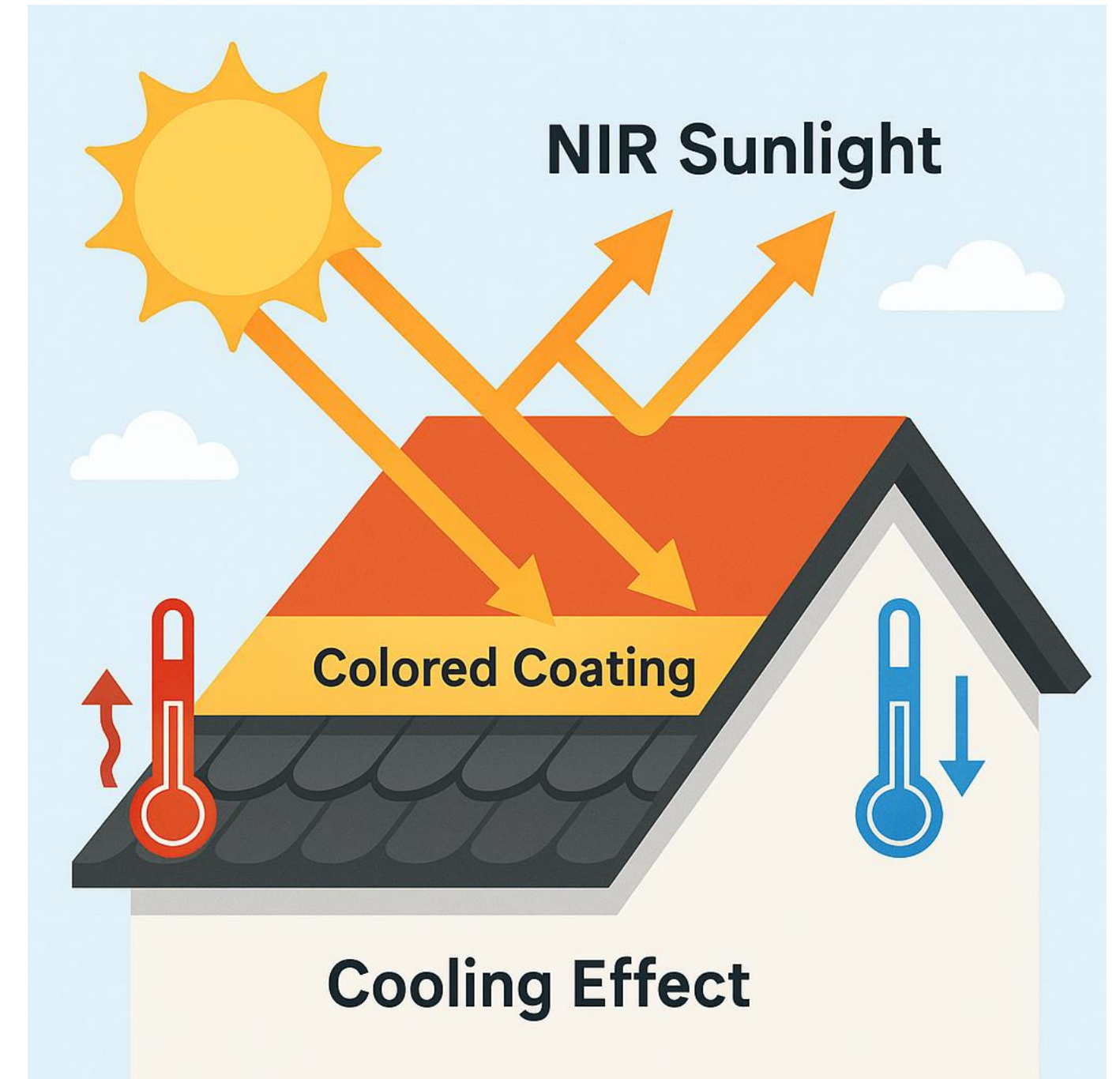
significant cooling effect of 4–5 °C already at the layer thickness of 150 µm



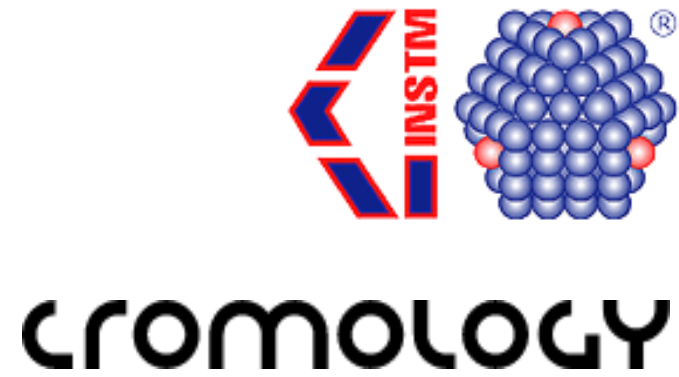
Conclusions

Combining thermoplastic hollow microspheres with NIR-transparent/reflective perylene pigments enhanced reflectivity on black substrates, leading to:

- increased SR up to values of 22% at the highest coating thickness;
- cooling features with temperature decreasing of at least 6°C with respect to the bare black substrate



Acknowledgements



Regione Toscana

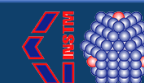


Le ali alle tue idee

Spesa finanziata dalla regione Toscana nell'ambito del POR FESR 2014-2020 - Bando 1 - Progetto "Coating organici per superfici NIR riflettenti" (COOLSUN)
Ammesso al contributo dalla Regione Toscana con Decreto Dirigenziale n. 5907 del 20/11/2015 e finanziato con Decreto Dirigenziale n. 12946 del 14/11/2016



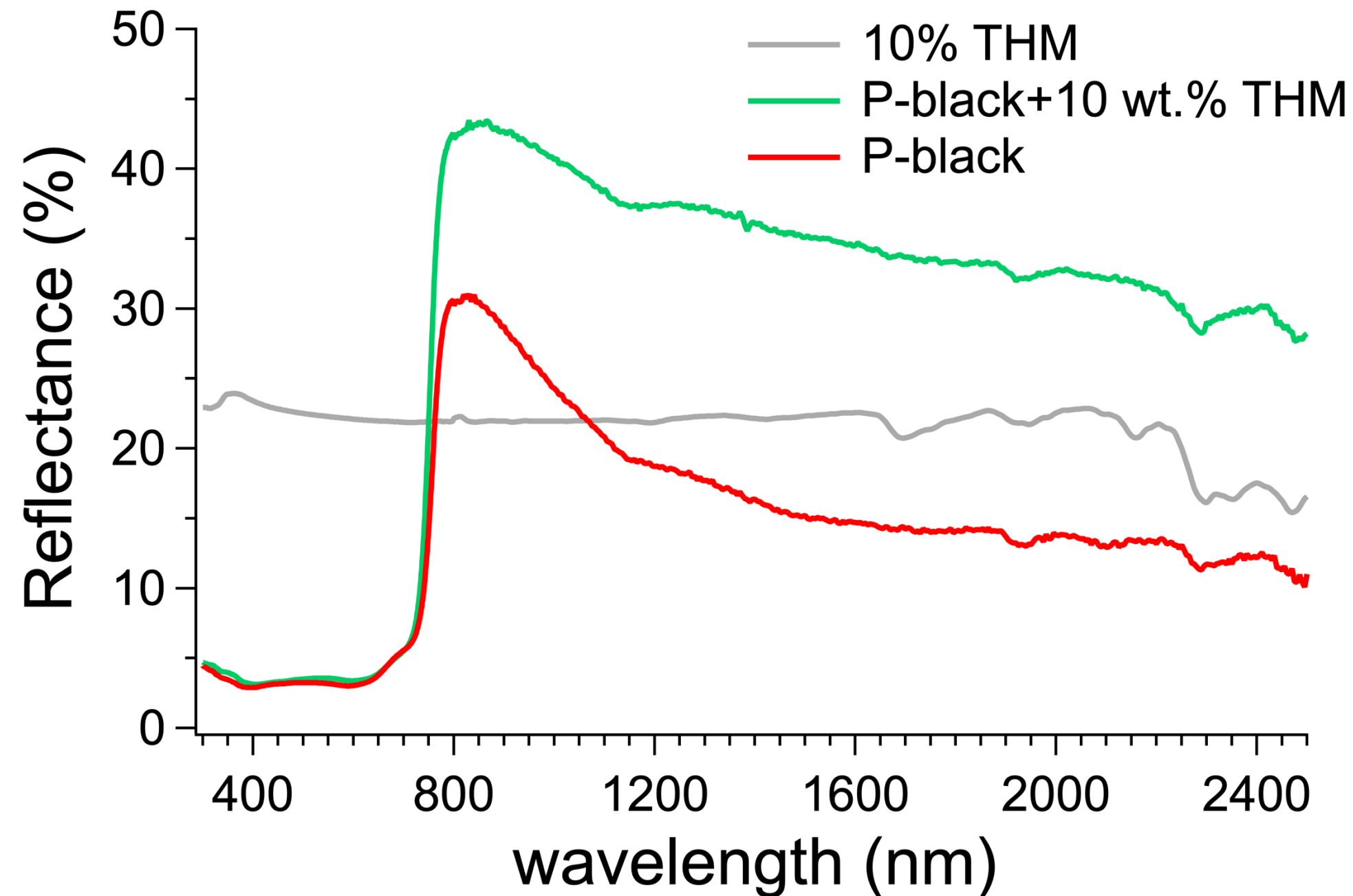
INSTM



UNIVERSITÀ DI PISA



B



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